

COLD

SPACE



The following pages describe the space environment simulation facilities installed and operating at the General Electric Valley Forge Space Technology Center. ¶ Designed specifically for use in ground testing advanced space vehicles, they comprise the largest complex of space environment simulation facilities in operation in this country. ¶ Available to industrial contractors and Government organizations for testing components, subsystems, systems, and complete spacecraft under solar, thermal-vacuum, and vibration conditions are a wide range of facilities—from 18-inch vacuum bell jars to a 54-foot-high by 32-foot-diameter solar-thermal-vacuum chamber. ¶ These very modern facilities are staffed by a highly experienced engineering organization furnished with the latest equipment to provide efficient and economical testing services. ¶ For more detailed information on how these facilities can be used in your testing program please contact:

Manager of Product Assurance
Spacecraft Department
General Electric Company
P.O. Box 8555, Philadelphia, Pennsylvania 19101
Telephone: Area Code 215-969-2373

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Space Environment Simulation Facilities

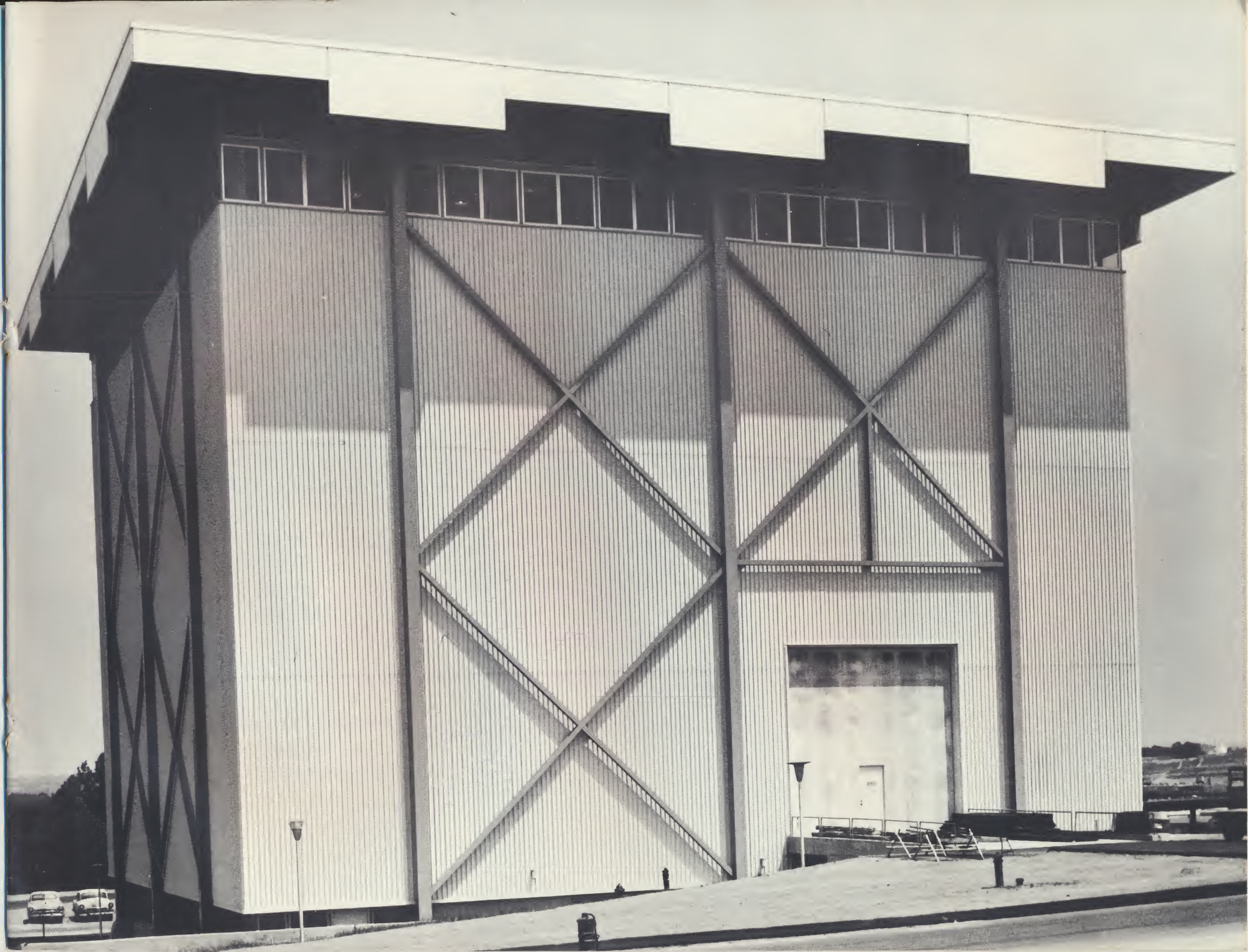


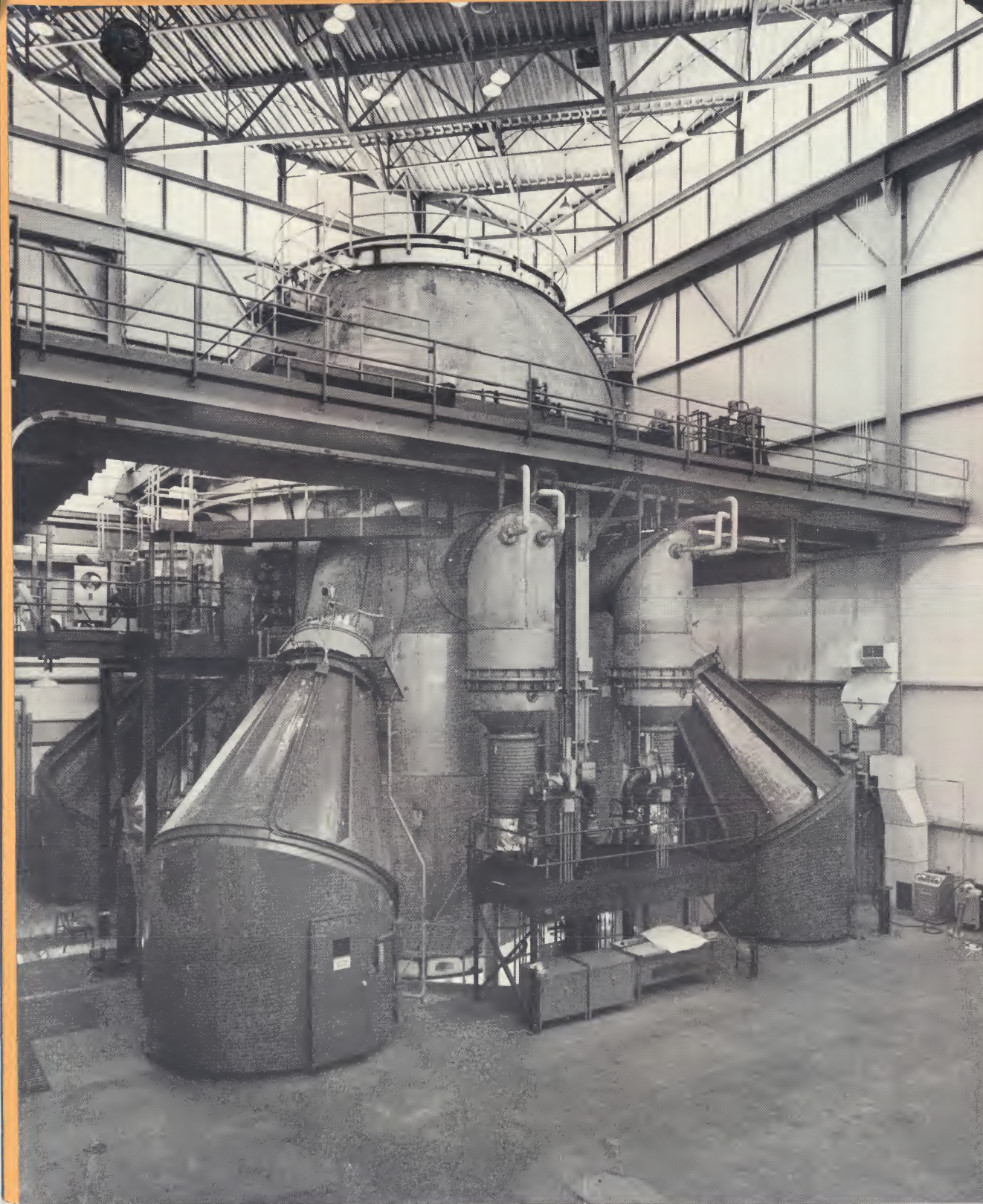
Simulation Facilities

Thorough, rigorous, preflight ground testing of spacecraft in thermal/vacuum chambers is accepted practice in U. S. space programs. However, as spacecraft become more complex and longer life and higher reliability are required, the sophistication of ground testing must also increase. ¶ The space simulation facilities at the General Electric Valley Forge Space Technology Center were specifically designed to provide this necessary degree of sophistication.

Space Environment Simulation Laboratory

Many unique conditions characterize the space environment, but the ones of major concern are essentially solar and planetary radiation, temperature, and vacuum. The Space Environment Simulation Laboratory was designed to effectively simulate these phenomena, and is among the finest existing space testing facilities. ¶ The laboratory is located in a separate building, 88-feet high by 100-feet square. Offices, control room, preparation area, and the 54-foot by 32-foot solar-thermal-vacuum chamber are located in the building. Access to the building can be controlled for classified or proprietary operations.





Solar-Thermal-Vacuum Chamber

The major component of the Space Environment Simulation Laboratory is the 54-foot high by 32-foot diameter solar-thermal-vacuum chamber. Capable of accommodating complete spacecraft up to 21 feet in diameter weighing as much as 44,000 pounds, the space chamber provides vacuum conditions from 10^{-6} to 10^{-9} torr and the cold black characteristics of space.

Cold Black Space

The interior surfaces of the solar-thermal-vacuum chamber are maintained at extremely low temperatures to simulate the low energy, completely absorbing characteristics of space. A system of black anodized cooling panels is employed through which liquid nitrogen is circulated. ¶ All surfaces facing a test vehicle have an emissivity of 0.95 or higher. The cryogenic panels are arrayed as shown in the schematic diagram and are covered with a three-quarter inch thick honeycomb. The baffle effect of the finned array combined with the multiple bounce path of the honeycomb produces the high emissivity. ¶ The cold black surfaces of the interior of the chamber simulate in appearance as well as effect the "cold and black" of space.

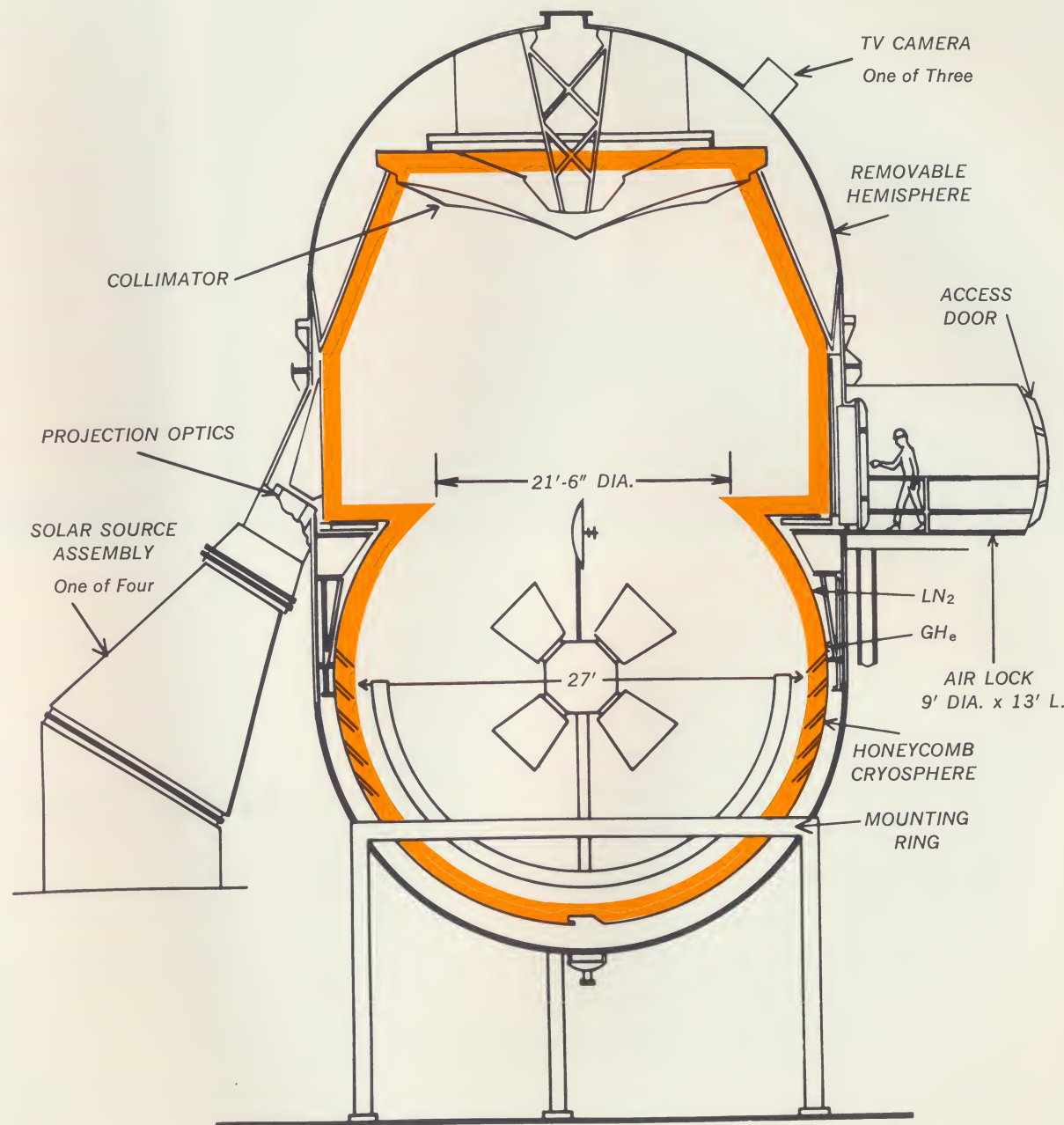
Solar Simulation

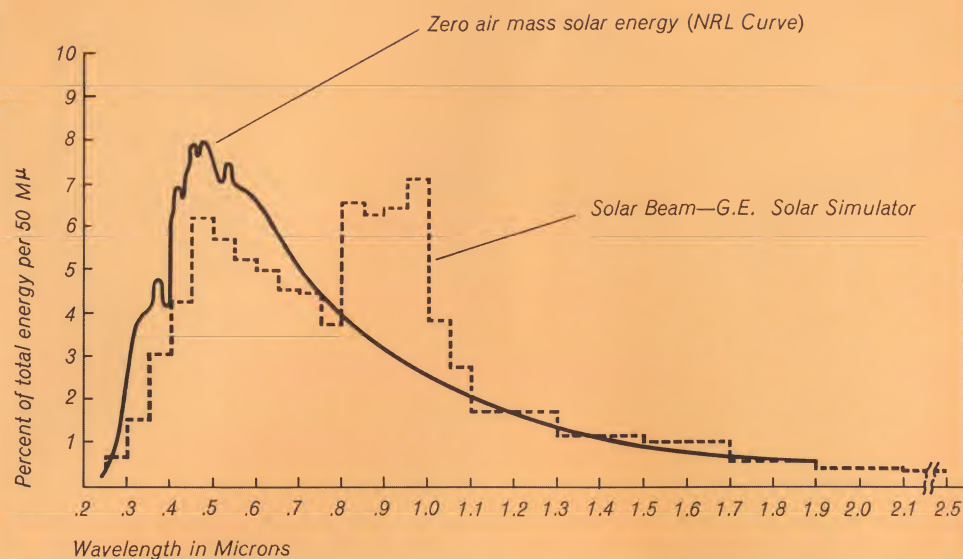
Xenon arc lamps and a unique optical system provide a 14-foot diameter collimated beam of simulated solar radiation. This "sun", among the largest in operation in this country, provides a variable intensity of 120-140 watts per square foot of solar radiation.

A study program to increase the collimated beam to 21 foot diameter has been initiated and will be completed by January 1967.

Supporting Facilities

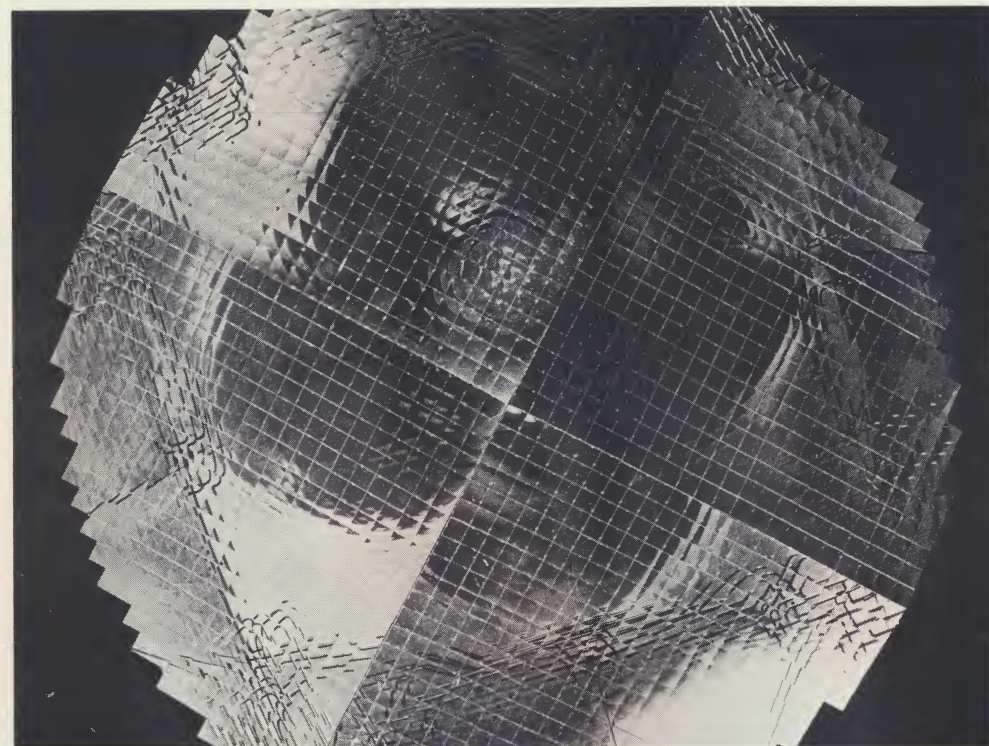
A test preparation area is located immediately adjacent to the chamber and an overhead crane is available for placing test vehicles in the chamber. ¶ The hemispherical dome of the cylindrical chamber is rolled completely back for easy access and personnel entry is provided through the side. The dome contains the parabolic reflectors for the solar simulation system and three penetrations for visual monitoring by means of closed circuit television. ¶ A two-axis positioning device capable of supporting vehicles weighting up to 5000 pounds is currently available for use in the chamber. Special positioning devices for specific needs can be designed and built for use with any shape or size test vehicle.





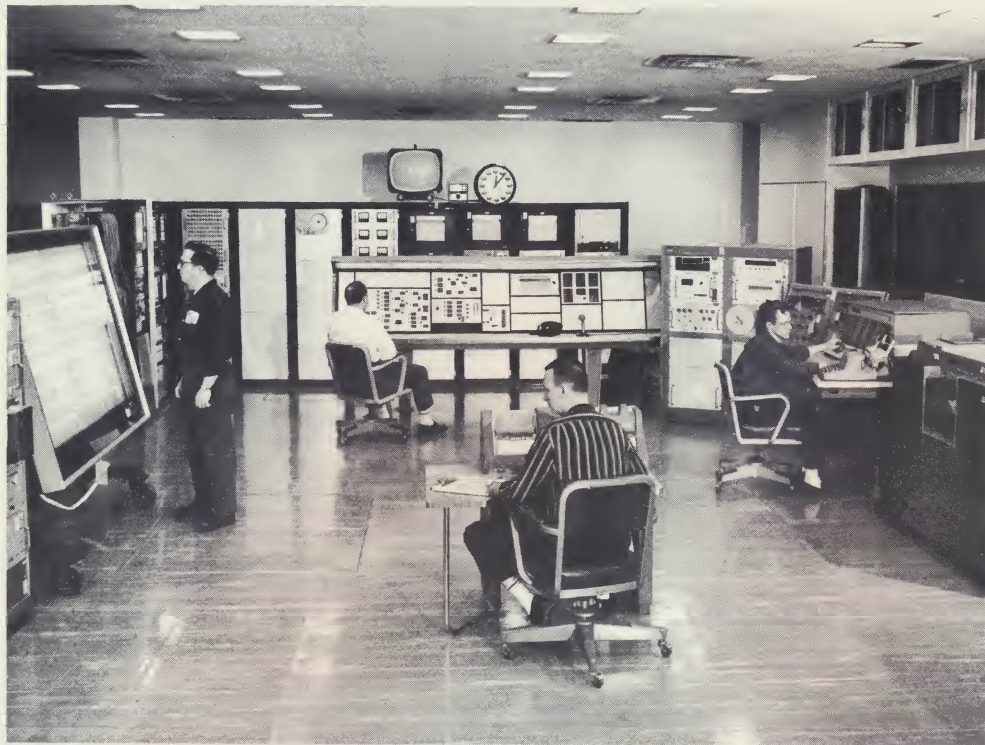
Spectral Characteristics

The 14-foot diameter collimated beam of simulated solar radiation provided in the space chamber is one of the "truest" suns available in this country. Four banks of lamps, each bank containing thirty-seven 5000-watt Xenon arc lamps, serve as the energy source. Radiant energy from the lamps enters the chamber through a quartz lens system, is reflected from an off-axis parabolic mirror, and is collimated to within 3° before it strikes the test vehicle. The intensity can be controlled from 120 to 140 watts per square foot. ¶ Distribution of the energy over the solar spectrum is shown in the graph above.



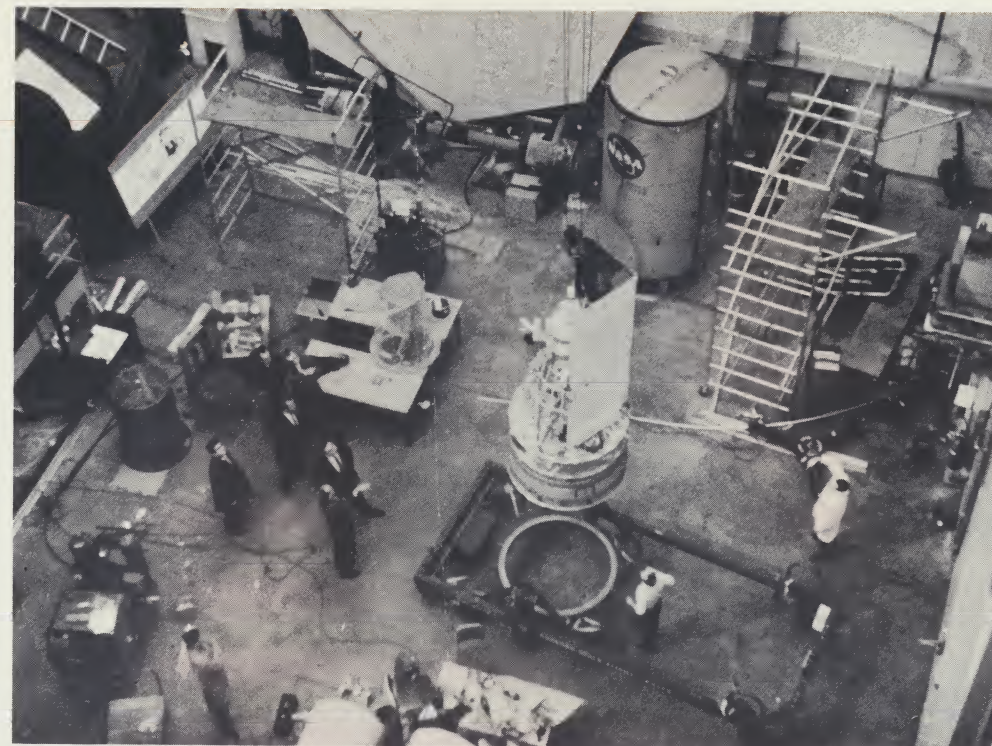
Primary Collimator

The primary collimator of the solar simulation system is made up of a mosaic of small mirrors. Each of the 1560 mirrors is twin-ground, front-surfaced, and measures approximately 6-inches square. Each adjustable mirror element is suspended at three points and is located on a quadrisected, off-axis parabolic support. The complete mirror assembly is shown in the photograph above. ¶ The off-axis design of the sun collimator makes it appear to the test spacecraft as cold and black as the chamber interior. Energy radiated from a test spacecraft to the collimating mirror is reflected to the cold chamber walls rather than re-radiated back to the spacecraft.



Instrumentation and Control

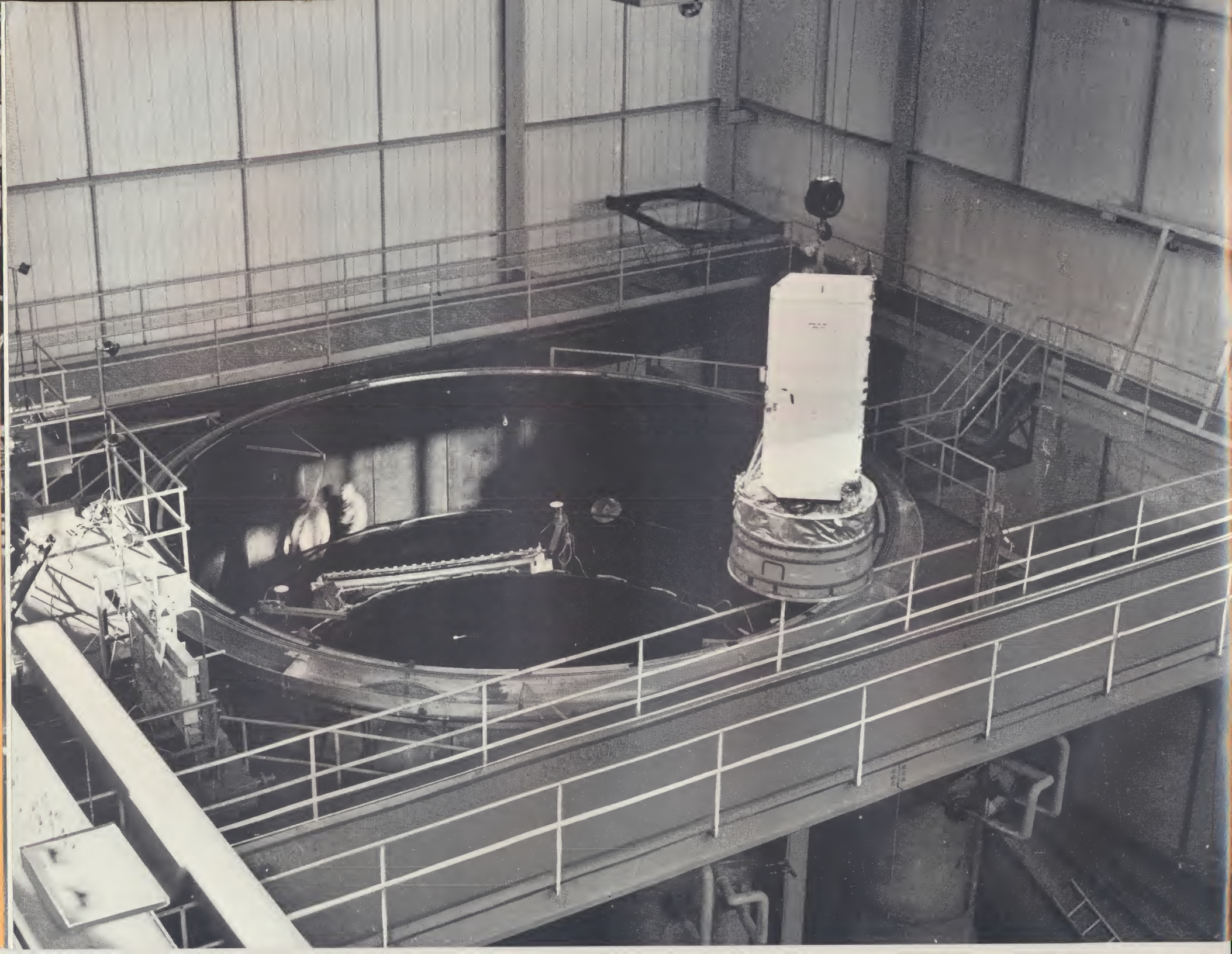
The control room for the solar-thermal-vacuum chamber is located on the second level of the Space Environment Simulation Laboratory. A single test conductor at a master console is responsible for operation of the chamber. The master console consists of a graphic display of each subsystem and start-stop and run controls. To eliminate possible confusion, only the information required for operating the system is included in the master console. A complete set of interlocks and permissive circuits gives the test conductor complete control against mis-operation. ¶ Sixteen penetrations in the chamber wall provide for power connections, strain gauges, thermocouples, and other devices to be attached directly to a test vehicle. Approximately 3000 test points can be monitored simultaneously. Near



real-time readout, processing, and computation of test data is available.

Preparation Area

Adequate preparation areas are available immediately adjacent to the chamber. A large area of the main level is kept clear for preparation and checkout of a test vehicle prior to installation in the chamber. Access to the area from the outside is through a 20- by 20-foot overhead door and an overhead crane is available. Free overhead space from the preparation floor measures 75 feet. Shown above is the NIMBUS weather satellite being prepared for testing. One of the solar system's four housings which enclose a bank of thirty-seven 5000-watt xenon lamps is seen in the upper left portion of the photograph.



Design Characteristics of Solar-Thermal-Vacuum Chamber

VACUUM CHAMBER

Size	Cylinder, 32' diameter x 54' high
Access	Upper hemisphere removable 40" x 84" door in side
Material	304 L stainless steel 3/4" thick
Vacuum	10^{-5} to 10^{-9} torr

VACUUM PUMPING

Cryogenic	100°K Condensables (LN_2) 3.4×10^8 Liters/second
	20°K Condensables (GHe) 2.3×10^6 Liters/second
Oil Diffusion	Non-Condensables (H_e , H_2 , N_e) 20,000 Liters/second

WALL EMISSIVITY >0.95

SOLAR SIMULATION

Source	148 5KW Xenon arc lamps
Collimator	Off-axis quadrisected glass mosaic paraboloid—22' diameter
Collimation	$\pm 3^\circ$ to $\pm 5^\circ$ (at outer edge)
Intensity	120-140 watts/ft ² (feedback control)
Uniformity	$\pm 10\%$ (volume and plane)
Maintenance	Lamps replaceable during operation

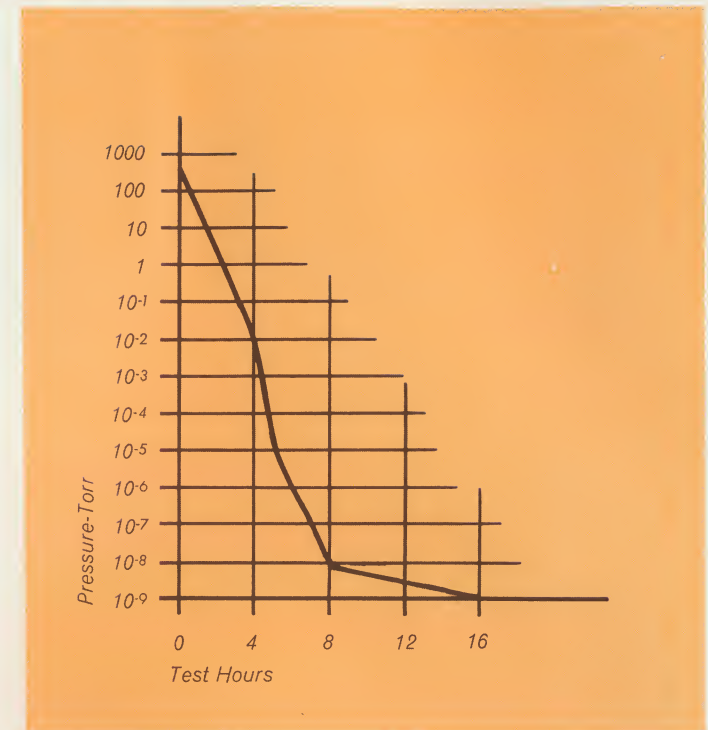
TEST CAPABILITY

Size	21' diameter sphere
Weight	44,000 pounds

OPERATING TIME

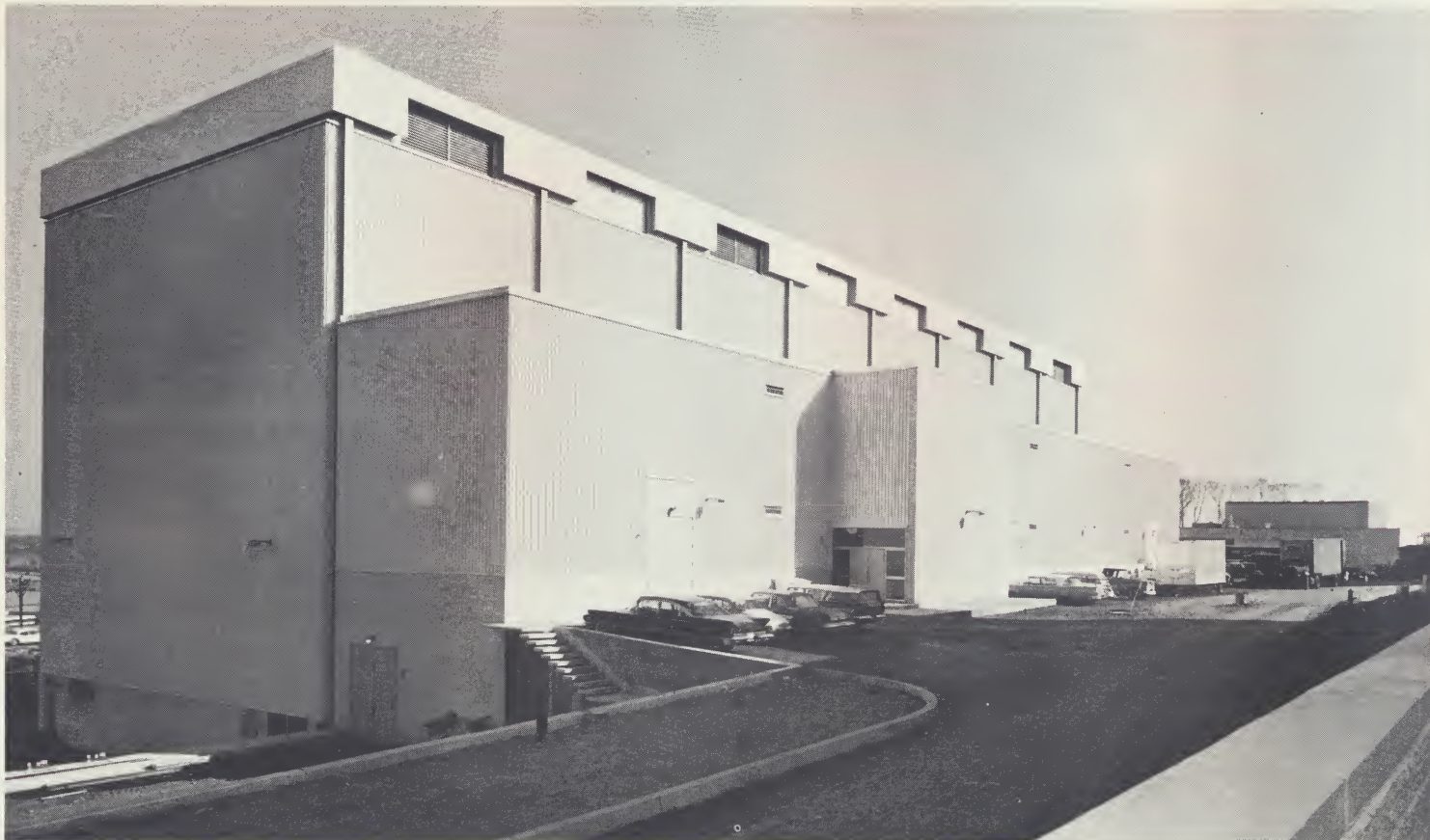
Start up	7 hours to 10^{-7} torr
Shutdown and warm up	20-24 hours

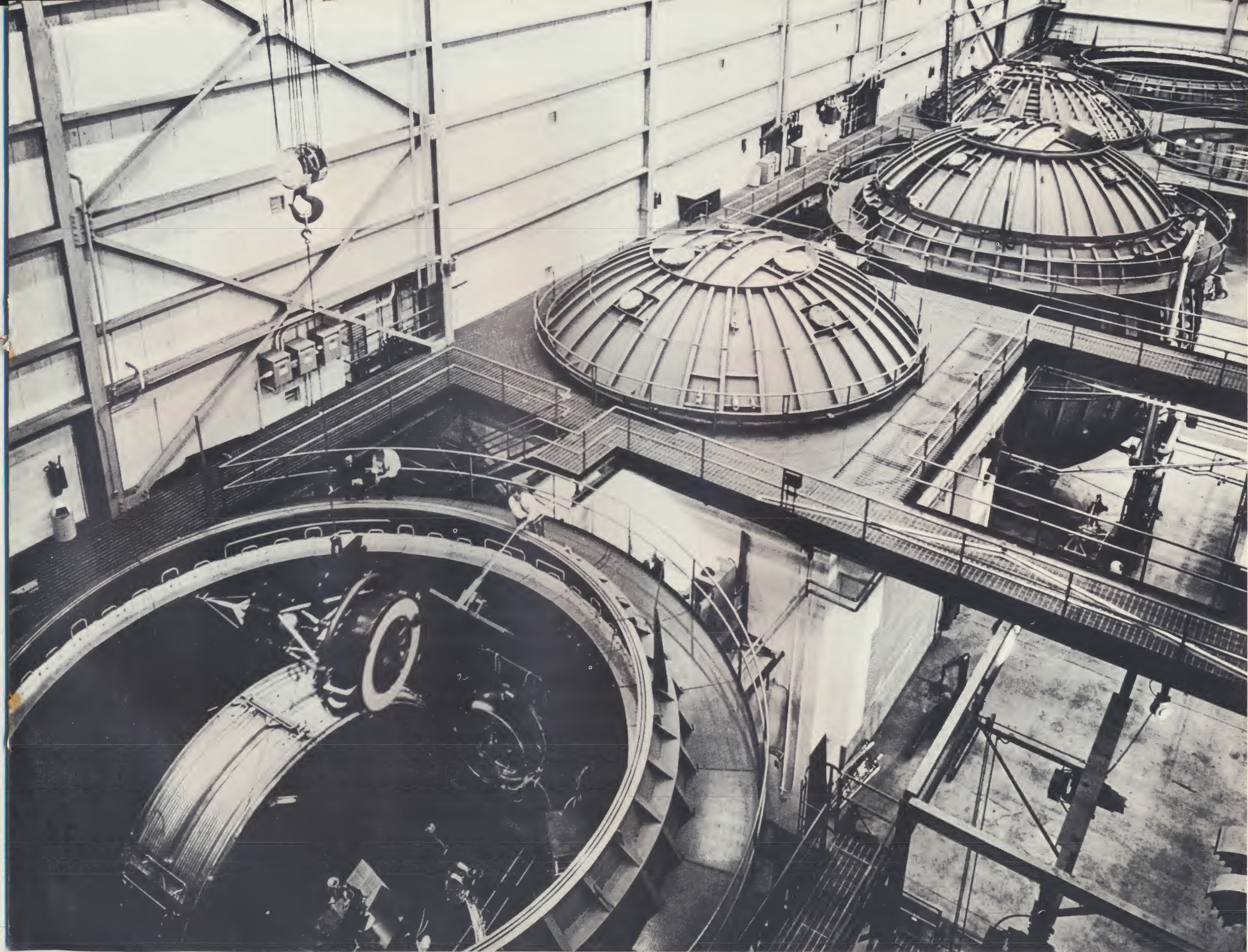
PUMP DOWN CURVE
SOLAR-THERMAL-VACUUM CHAMBER



The Space Environment Test Facility is a separate building designed and constructed specifically to meet the demands of utility and flexibility required for environmental testing of full-scale spacecraft systems. ¶ The building is 240-feet long, 100-feet wide and 82-feet high and houses three spherical thermal-vacuum chambers 39-feet in diameter and one 12-x 26-foot horizontal cylindrical chamber. These environmental chambers are designed to subject sub-systems or complete spacecraft to thermal vacuum conditions during the development, acceptance, and qualification stages of the spacecraft cycle. ¶ The building also contains the necessary office space, control room, preparation areas, and other supporting equipment.

*Space
Environment
Test
Facility*

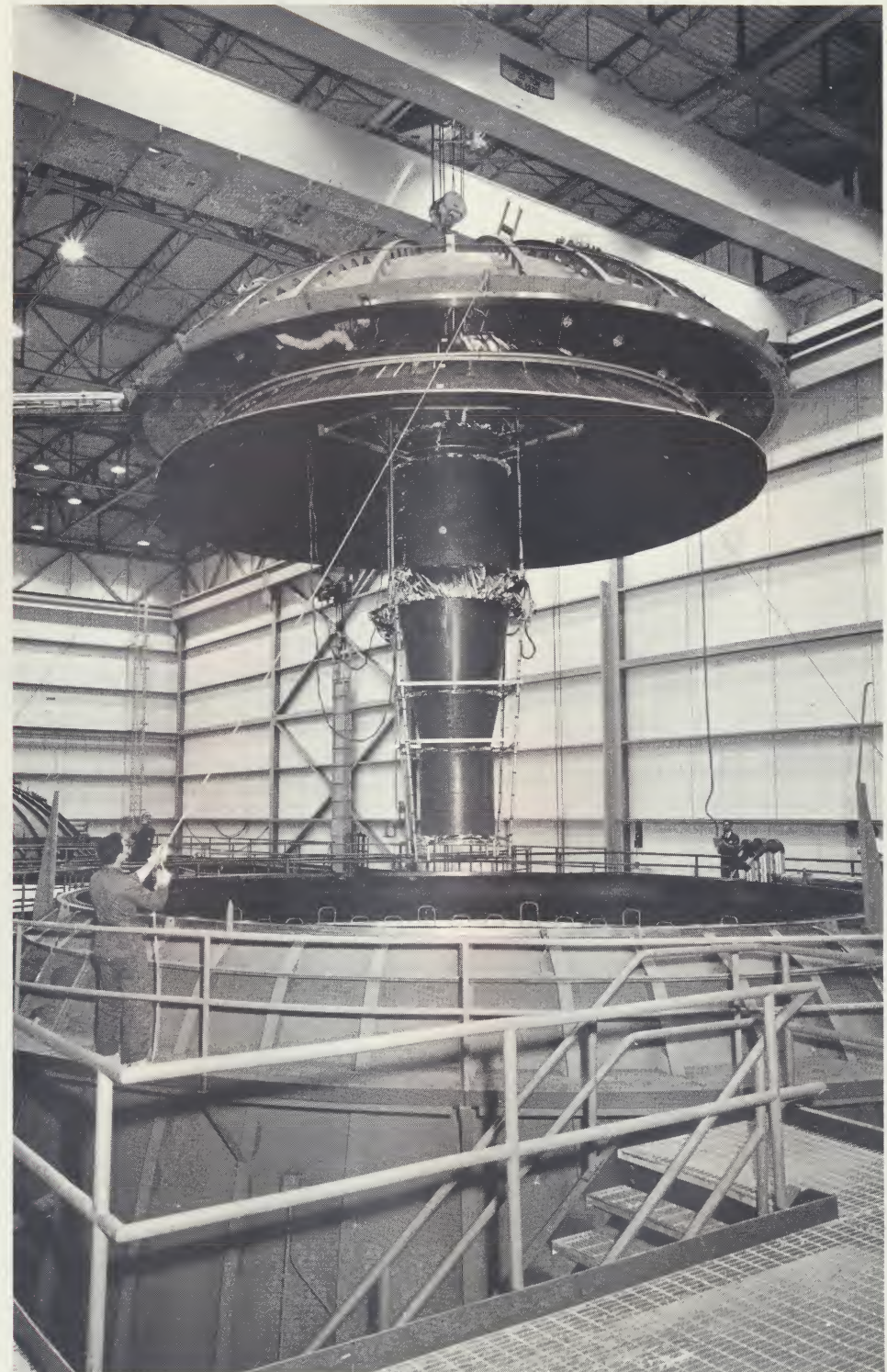




39-Foot Thermal-Vacuum Chambers

The three 39-foot diameter thermal-vacuum chambers in the Space Environment Test Facility are capable of accommodating test spacecraft up to 21-feet in diameter and 30-feet long, weighing up to 20,000 pounds. The chambers provide vacuum conditions from 10^{-5} to 10^{-9} torr and the cold black characteristics of space. ¶ The chambers utilize liquid nitrogen (90°K) and dense gaseous helium (20°K) for cryogenic pumping. ¶ The chambers provide a capability for conducting space environment tests where true solar simulation is not a requirement. However, a programmable infrared heating system is available to produce the known or predicted thermal characteristics of a test vehicle.

A control room area, 29-feet wide, for the Space Environment Test Facility extends the entire length of the building. The environmental control equipment for the vacuum and cryogenic system is located in this area as well as test control and readout instrumentation. The area can be made as secure as required through the use of partitions, alarms and other security measures. ¶ Each of the three chambers is independently operated from its own master console. A closed circuit television system and an intercom system allow direct communication within the test areas.



A typical space craft is lowered into 39-foot thermal-vacuum chamber for testing.

VACUUM CHAMBER

Size	3 spheres, 39' diameter
Access	Upper hemisphere removable 48" x 96" door in side
Material	304 L stainless steel 3/8" thick with reinforcing ribs
Vacuum	10 ⁻⁵ to 10 ⁻⁹ torr

VACUUM PUMPING

Cryogenic	100°K condensables (LN ₂) 3.0 x 10 ⁸ Liters/second 20°K condensables (GHe) 3.0 x 10 ⁶ Liters/second
Oil Diffusion	Non-Condensables (H _e , H ₂ , N _e) 50,000 Liters/second

WALL EMISSIVITY >0.9

TEST CAPABILITY

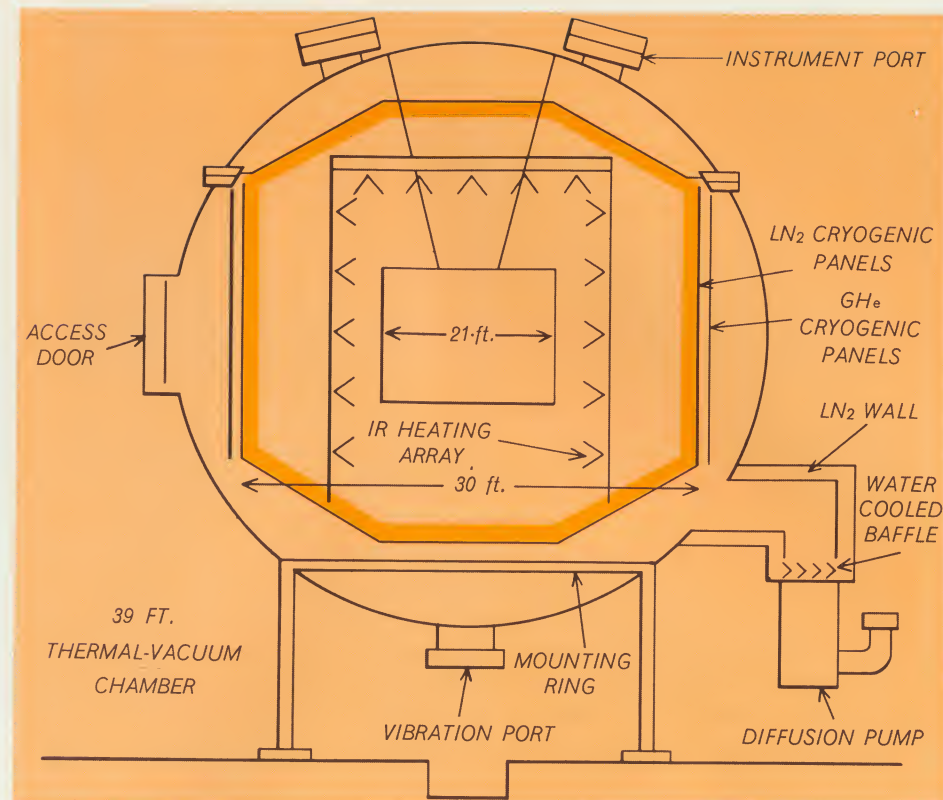
Size	Cylinder, 21' diameter x 30' high
Weight	20,000 lbs.

OPERATING TIME

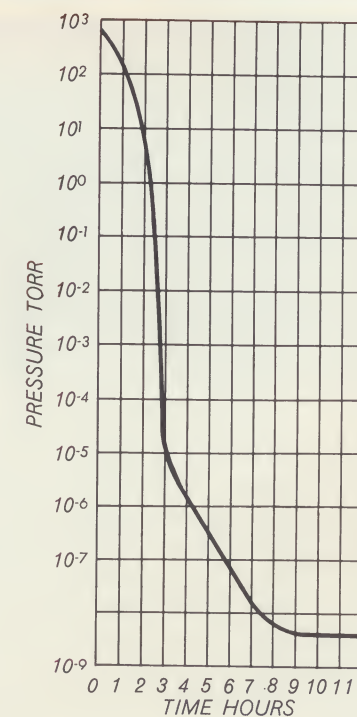
Start up	6 hours to 10 ⁻⁷ torr
Shutdown and warm up	12 hours (nominal)

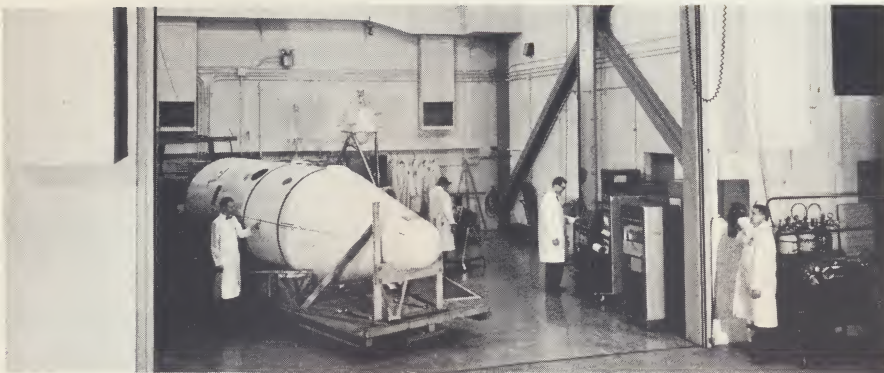
THERMAL ENVIRONMENT

IR heating	5-390 watts/ft ² multiple zone controllable
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PUMP DOWN CURVE
OF 39-FOOT
THERMAL-VACUUM CHAMBER

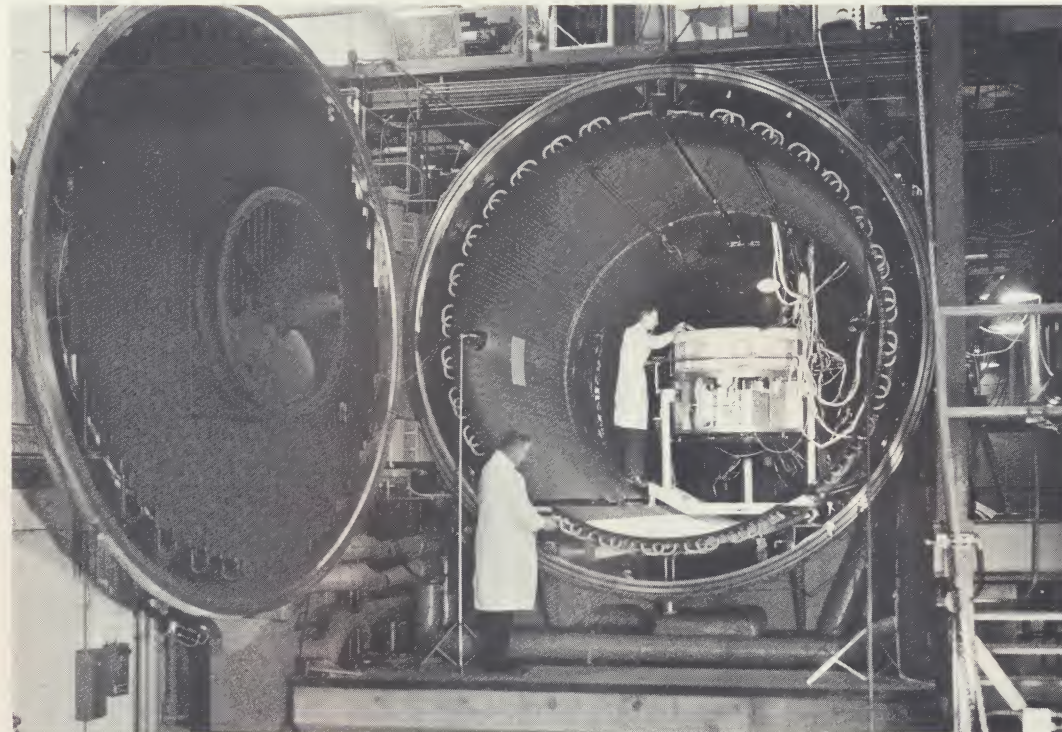




Two enclosed preparation areas are provided in the Space Environment Test Facility for the set-up, checkout and assembly of test hardware and support instrumentation. The hardware is usually brought into the area through the 30' x 30' door. The preparation areas are air conditioned, with 1000 square feet of floor space and a head-room of 30 feet. A test vehicle can be prepared while resting on a 5-ton hydraulic platform or while attached to a chamber cover. An overhead 25-ton crane can then transfer the vehicle and cover to a designated chamber. These preparation areas can be easily converted into "Security" areas for classified programs.



A programmable infrared radiant heating system is available in two of the 39-foot thermal-vacuum chambers providing a heat capacity variable between 5 and 390 watts per square foot with a uniformity of $\pm 5\%$. These heating arrays are programmable by zone to provide accurate simulation of the test vehicle's predicted temperature characteristics. The temperature in each of the controlled zones can be varied as required. Program control for heater blanket arrangements are available for all three 39-foot thermal-vacuum chambers.



The 12- x 26-foot thermal-vacuum chamber in the Space Environment Test Facility has a vacuum capability in the 10^{-5} to 10^{-8} torr range. In addition to the 90°K cold shroud, a brine system to produce -100°F to $+250^{\circ}\text{F}$ walls is available. When the brine system is used the ultimate vacuum is 10^{-5} torr. The chamber is equipped with a monorail and serviced with a hydraulic lift; it is dynamically isolated on a seismic mass that reduces vibration displacement to 10 microns permitting precise optical measurements to be made on the test specimen. An optical viewing port is located at the end of the chamber.





One of the largest vibration systems in the country is available to test complete spacecraft or large subsystems. The vibration laboratory is located in a separate building and is equipped with two MB Company type C-210 shakers. A large seismic mass is isolated by isomode columns and is capable of holding six of the large shakers. Distance between the shakers can be varied up to 50 feet. The building is serviced by a 15-ton crane. Maximum overhead clearance is 61 feet.

Building Size: 50' x 50' x 85'

Force Output: (each head)

Peak Sine 25,000 lbs.

Random (RMS) 17,700 lbs.

Frequency: 5-2000 cps

Stroke: 1-inch double amplitude

Instrumentation:

Wide band FM magnetic tape (100 data channels)

Multiple channel recording oscillographs

On-site data reduction

Additional Environmental Facilities



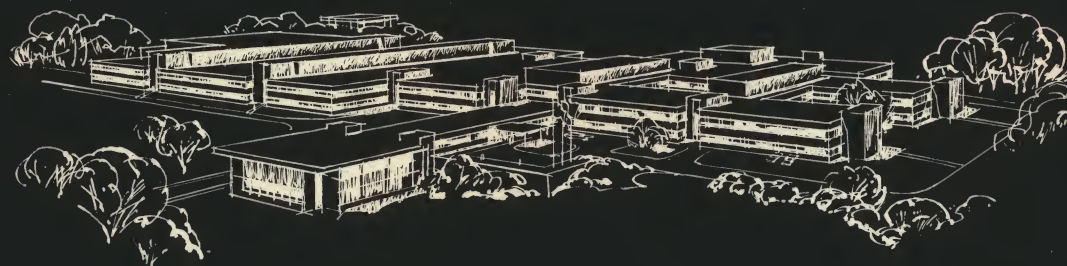
Four thermal-vacuum chambers are available for subsystem and component testing. These chambers are five-feet in diameter by five-feet high and have a vacuum capability of 1×10^{-8} torr with 90°K wall temperature. A helium shroud at 20°K is also available. They can be used to perform heat transfer, surface phenomena, bearing studies and outgassing effects on component and subsystems.



A 10- x 12-foot thermal-vacuum chamber is available for component and subsystem testing. In addition to the cold (90°K) shroud a brine shroud is available with a -100°F to +200°F capacity. Vacuum is in the 10^{-5} to 10^{-7} torr range. Heat fluxes are created with infra-red and heat blanket arrays.

Simulator Tests and Experience

The General Electric Company has conducted a variety of tests in the solar simulator and the thermal-vacuum chambers as part of major NASA and DOD projects. Included are the following: ¶ THERMAL BALANCE TESTS—Tests were conducted in a large spacecraft (classified) to determine its thermal profile in the space environment. The temperature of over 1000 points in the spacecraft was determined and information obtained led to several changes in design. These resulting changes contributed to the success of the spacecraft's subsequent flight. ¶ SYSTEM QUALIFICATION TEST—A Nimbus spacecraft prototype with all subsystems except solar paddles was tested on an air bearing in a 39-foot thermal-vacuum chamber to measure the performance of all systems while in a cold, hard vacuum. All subsystems were either exercised or "functionally" tested continuously for 18 days. ¶ SOLAR PADDLE TRACKING SUBSYSTEM TEST—The response of a spacecraft's solar paddle tracking subsystem was determined by subjecting the vehicle to solar simulation in the solar-thermal-vacuum chamber. ¶ SOLAR INTENSITY TEST—By positioning a solar probe model close to the focal point of the solar system lens assembly it was possible to illuminate the vehicle to an intensity of ten solar constants. Data was obtained on internal temperature gradients, solar paddle temperatures, and the effectiveness of spacecraft thermal control coatings. ¶ PROPELLANT STORAGE TEST—Tests to determine the boil-off of propellants stored during long-term space missions were conducted in the solar-thermal-vacuum chamber. In this test insulated fuel tanks were exposed to the space environment under full solar illumination and boil-off was physically measured. ¶ MANNED SPACE CABIN TEST—A 30-day test of a four-man crew in a sealed simulated space station was conducted in a 39-foot thermal-vacuum chamber. In addition, a two-man 15-day test was conducted in the 54-foot solar-thermal-vacuum chamber. An artificial atmosphere of nitrogen and oxygen at one-half sea level pressure was maintained continuously. Experiments carried out during the test yielded data relative to the ability of men to function effectively during a long-duration space mission. ¶ GEMINI ASTRONAUT MANEUVERING UNIT (back pack) plume pattern and Fuel Cell qualification and acceptance tests were performed in 39-foot thermal vacuum facility. ¶ GRAVITY GRADIENT TEST SATELLITE—A GGTS vehicle was tested in the 32- x 54-foot simulator under one solar constant to evaluate the lump-mass thermal control design of the vehicle. The test was conducted simulating a full mission orbital profile. ¶ SATURN IV B LIQUID HYDROGEN AND LIQUID OXYGEN VENT AND RELIEF VALVES—Crack, reseal pressure, and leakage were evaluated in a simulated space environment created in a 39-foot diameter thermal-vacuum chamber. ¶ APOLLO BLOCK I AND BLOCK II ECS (ENVIRONMENT CONTROL SYSTEM) AND EPS (ELECTRICAL POWER SYSTEM) RADIATORS—Thermal evaluation tests were conducted in the solar-thermal-vacuum chamber using a gimbal support structure. ¶ SNAP 27 HEAT REJECTION TESTS during simulated lunar night and day cycles were conducted in the 8 x 10 facility. ¶ APPLICATIONS TECHNOLOGY SATELLITE ORBIT TEMPERATURE STABILIZATION TEST was conducted in 8 x 10 vacuum facility. ¶ ORBITING ASTRONOMICAL OBSERVATORY SOLAR IMPINGEMENT TESTS eliminating light scattering caused by atmospheric dust particles are performed on star trackers and television cameras in the 39-foot thermal vacuum facility. ¶ NRL (Naval Research Laboratory) MULTI-FACE SATELLITE THERMAL ANALYSIS AND EVALUATION TESTS using selected optical coatings were performed in the 8 x 10 thermal facility. ¶ MARK 12 SHROUD SEPARATION TESTS were conducted in the 39-foot thermal vacuum facility.



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MISSILE AND SPACE DIVISION • VALLEY FORGE SPACE TECHNOLOGY CENTER • P.O. BOX 8555, PHILADELPHIA, PENNSYLVANIA 19101